

**APPLICATION FOR
UNITED STATES PATENT**

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entitled

**LIGHT-EMITTING DEVICE AND MANUFACTURING PROCESS
OF THE LIGHT-EMITTING DEVICE**

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by inventors

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LIGHT-EMITTING DEVICE AND MANUFACTURING PROCESS OF THE LIGHT-EMITTING DEVICE

5 Field of the Invention

[0001] The present invention generally relates to light-emitting devices, and particularly to the structure and manufacture of a white light-emitting device.

Description of the Related Art

10 [0002] A white light-emitting diode device usually implements the principle of color additive mixing to produce white light. The structure of a white light-emitting device conventionally includes at least two luminescent layers. A first luminescent layer is capable of emitting a first light radiation when subjected to an electric current flow. Upon stimulation of the first light radiation, a second luminescent layer emits a
15 second light radiation which, being combined with the first light radiation, produces white light.

[0003] FIG. 1 is a schematic view of a white light-emitting diode known in the art. The white light-emitting device 10 includes a light-emitting diode 12 formed on a zinc-selenium (ZnSe)-based substrate 14. The light-emitting diode 12 conventionally
20 include a plurality of layers (not shown) that may be either formed by epitaxy growth or attached on the ZnSe-based substrate 14. The light-emitting diode 12 and the substrate 14 are mounted on a support frame 16. Electrodes 18 of the light-emitting diode 12 are connected via wires 20 to contact leads 22. A reflective layer 24 is placed below the ZnSe-based substrate 14 to direct light towards the viewer side. Upon the

application of an electric current, the light-emitting diode 12 conventionally emits a first radiation of blue (B) light. Being stimulated by the blue light, the ZnSe-based substrate 14 in turn emits a second radiation of yellow (Y) light. The combination of blue and yellow lights results in a white light perceived by the viewer.

5 [0004] In operation, the prior structure of light-emitting device appears to have a service life that is unsatisfactorily limited. One reason of this limitation may be a crystalline mismatch caused by the direct attachment or formation by growth of the layers constituting the light-emitting device on the ZnSe-based substrate. Therefore, there is presently a need for the structure of a light-emitting device, particularly
10 implemented to emit white light, which can have an improved service life.

SUMMARY OF THE INVENTION

[0005] The application describes a light-emitting device and a manufacturing process of the light-emitting device. In one embodiment, a light-emitting device
15 comprises a light-emitting unit including a plurality of first connecting pads, a base substrate including a plurality of second connecting pads, and a plurality of conductive bumps that connect the first connecting pads of the light-emitting unit to the second connecting pads of the base substrate. The light-emitting unit is configured to emit a first light radiation, and the base substrate is configured to emit a second light radiation
20 when stimulated by the first light radiation.

[0006] In another embodiment, a process of forming a light-emitting device comprises forming a light-emitting unit provided with a plurality of first connecting pads, forming a base substrate provided with a plurality of second connecting pads, and

connecting the light-emitting unit to the base substrate by means of a plurality of
conductive bumps that bond the first connecting pads to the second connecting pads.
The light-emitting unit is configured to emit a first light radiation, and the base substrate
is configured to emit a second light radiation when stimulated with the first light
5 radiation.

[0007] The foregoing is a summary and shall not be construed to limit the scope of
the claims. The operations and structures disclosed herein may be implemented in a
number of ways, and such changes and modifications may be made without departing
from this invention and its broader aspects. Other aspects, inventive features, and
10 advantages of the invention, as defined solely by the claims, are described in the
non-limiting detailed description set forth below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a schematic view of a white light-emitting device known in the art;

15 [0009] FIG. 2A~2C are schematic views of a white light-emitting device according
to various embodiments of the invention;

[0010] FIG. 3A~3H are schematic views of forming a light-emitting unit for a white
light-emitting device according to an embodiment of the invention;

[0011] FIG. 4A~4E are schematic views of a process of forming a base substrate for
20 a white light-emitting device according to various embodiments of the invention;

[0012] FIG. 5A~5B are schematic views of a process of mounting a light-emitting unit to a base substrate to form a white light-emitting device according to an embodiment of the invention; and

[0013] FIG. 5C is a flowchart describing a process of manufacturing a white
5 light-emitting device according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE EMBODIMENT(S)

[0014] FIG. 2A is a schematic view of a light-emitting device according to an embodiment of the invention. The light-emitting device includes a light-emitting unit
10 100 mounted to a base substrate 200 via conductive bumps 118. The light-emitting unit 100 is configured to emit a first light radiation. The base substrate 200 is configured to emit a second light radiation when stimulated by the first light radiation. The combination of the first and second light radiations results in a perception of a specific light color by the viewer. In the description herein, the light-emitting unit is
15 exemplary illustrated as a light-emitting diode, but it is understood that the inventive features described herein can be generally implemented with any structures of light-emitting source.

[0015] The light-emitting unit 100 includes a light-emitting area 122 and an adjacent area 124. In the light-emitting area 122, a stack structure of the light-emitting
20 unit 100 includes a substrate 102, a first cladding layer 104, an active layer 106, a second cladding layer 108 and a first ohmic contact layer 110. In the adjacent area 124, a portion of the first cladding layer 104 is covered with a second ohmic contact layer 112. A protective layer 114 is formed to cover a portion of the light-emitting unit 100

while exposing connecting pad areas 110a, 112a of the first and second ohmic contact layers 110, 112. Connecting pads 116 are respectively formed in contact with the exposed connecting pad areas 110a, 112a of the first and second ohmic contact layers 110, 112.

5 **[0016]** The base substrate 200 is formed from a stack structure that includes a substrate 202, a luminescent layer 204, a passivation layer 206 and connecting pads 208. Conductive bumps 118 connect the connecting pads 116 of the light-emitting unit 100 to the connecting pads 208 of the base substrate 200. Upon the application of a voltage bias between the connecting pads 208 of the base substrate 200, the
10 light-emitting unit 200 emits a first light radiation. In an embodiment, the first light radiation can encompass a wavelength range of blue color. Stimulated by the first light radiation, the luminescent layer 204 of the base substrate 200 emits a second light radiation different from the first light radiation. In an embodiment, the second light radiation can encompass a wavelength range of yellow color. The combination of the
15 first and second light radiations results in a perception by the viewer of a specific light color, i.e. white light emission, from the light-emitting device.

[0017] Many variations of the foregoing implementation can be envisaged. In FIG. 2B, the base substrate 200 can additionally include a reflective layer placed between the substrate 202 and the luminescent layer 204. The reflective layer can act to reflect
20 light towards the viewer side. In the example of FIG. 2C, the substrate 202 can be omitted. Though not detailed herein, it is understood that other variant embodiments with respect to the structure of the light-emitting unit 100 can be further envisaged in accordance with the inventive features described herein.

[0018] FIG. 3A~3H are schematic views of a process of forming a light-emitting unit 300 according to an embodiment of the invention. In FIG. 3A, a first cladding layer 304 is formed on a substrate 302. The substrate 302 can be made of a transparent electrically insulating material such as sapphire, SiC or the like. The first cladding layer 304 can include a group III nitride compound semiconductor material such as AlN, GaN, InN, AlGa_N, InGa_N, InAlGa_N or the like. In an example of processing, a metal organic vapor phase epitaxy process can be conducted to form the group III nitride compound semiconductor, using a mixture of gasses including carrier gas H₂ or N₂, trimethylgallium (Ga(CH₃)₃, or "TMG"), trimethylaluminum (Al(CH₃)₃, or "TMA"), trimethylindium (In(CH₃)₃, or "TMI"), silane (SiH₄), and cyclopentadienylmagnesium (Mg(C₅H₅)₂). N-type doping impurities such as silicon (Si), germanium (Ge), selenium (Se), sulfur (S), tellurium (Te) or the like, can be further introduced to dope the first cladding layer 304.

[0019] In FIG. 3B, an active layer 306 is formed on the first cladding layer 304. The active layer 306 can include either a single well structure or multi-quantum well structure layer. A multi-quantum structure layer is composed of an alternate lamination of well and barrier layers, including at least one layer made of a group III nitride compound semiconductor material.

[0020] In FIG. 3C, a second cladding layer 308 is formed on the active layer 306. The second cladding layer 308 can include a group III nitride compound semiconductor material such as AlN, GaN, InN, AlGa_N, InGa_N, InAlGa_N or the like. The second cladding layer 308 is doped with impurities of a conductance type opposite to that of the first cladding layer 304. In a case where the first cladding layer 304 is doped with

n-type dopants, the second cladding layer 308 can be accordingly doped with p-type dopants.

[0021] In FIG. 3D, an ohmic contact layer 310 is formed on the second cladding layer 308. Many types of conductive materials can be adequate to form the ohmic contact layer 310 including metallic alloys such as Ni/Au, Ni/Pt, Ni/Pd, Ni/Co, Pd/Au, Pt/Au, Ti/Au, Cr/Au, Sn/Au, Ta/Au, TiN, TiWN_x, WSi_x or the like. Alternatively, the ohmic contact layer 310 can be also made of a transparent conductive oxide such as indium tin oxide, cadmium tin oxide, ZnO:Al, ZnGa₂O₄, SnO₂:Sb, Ga₂O₃:Sn, AgInO₂:Sn, In₂O₃:Zn, NiO, MnO, FeO, Fe₂O₃, CoO, CrO, Cr₂O₃, CrO₂, CuO, SnO, Ag₂O, CuAlO₂, SrCu₂O₂, LaMnO₃, PdO or the like.

[0022] In FIG. 3E, a pattern mask 370 is formed on the ohmic contact layer 310. The pattern mask 370 can be a photoresist pattern deposited on the ohmic contact layer 310 via a photolithography process. An etching process is conducted through the pattern mask 370 to define a light-emitting area 382 covered by the pattern mask 370 and expose a portion of the first cladding layer 304 in an area 384 adjacent to the light-emitting area 382.

[0023] As shown in FIG. 3F, the pattern mask 370 then is removed, and another ohmic contact layer 312 is formed on the exposed portion of the first cladding layer 304 in the area 384. The ohmic contact layer 312 can be made of a metallic alloy including Ti/Al, Ti/Al/Ti/Au, Ti/Al/Pt/Au, Ti/Al/Ni/Au, Ti/Al/Pd/Au, Ti/Al/Cr/Au, Ti/Al/Co/Au, Cr/Al/Cr/Au, Cr/Al/Pt/Au, Cr/Al/Pd/Au, Cr/Al/Ti/Au, Cr/Al/Co/Au, Cr/Al/Ni/Au, Pd/Al/Ti/Au, Pd/Al/Pt/Au, Pd/Al/Ni/Au, Pd/Al/Pd/Au, Pd/Al/Cr/Au, Pd/Al/Co/Au, Nd/Al/Pt/Au, Nd/Al/Ti/Au, Nd/Al/Ni/Au, Nd/Al/Cr/Au, Nd/Al/Co/A, Hf/Al/Ti/Au,

Hf/Al/Pt/Au, Hf/Al/Ni/Au, Hf/Al/Pd/Au, Hf/Al/Cr/Au, Hf/Al/Co/Au, Zr/Al/Ti/Au,
 Zr/Al/Pt/Au, Zr/Al/Ni/Au, Zr/Al/Pd/Au, Zr/Al/Cr/Au, Zr/Al/Co/Au, TiN_x/Ti/Au,
 TiN_x/Pt/Au, TiN_x/Ni/Au, TiN_x/Pd/Au, TiN_x/Cr/Au, TiN_x/Co/Au TiWN_x/Ti/Au,
 TiWN_x/Pt/Au, TiWN_x/Ni/Au, TiWN_x/Pd/Au, TiWN_x/Cr/Au, TiWN_x/Co/Au,
 5 NiAl/Pt/Au, NiAl/Cr/Au, NiAl/Ni/Au, NiAl/Ti/Au, Ti/NiAl/Pt/Au, Ti/NiAl/Ti/Au,
 Ti/NiAl/Ni/Au, Ti/NiAl/Cr/Au or the like.

[0024] In FIG. 3G, a passivation layer 314 is formed to cover a portion of the stack structure while leaving exposed areas 310a, 312a of the first and second ohmic contact layers 310, 312. The passivation layer 314 can be made of a dielectric material such as
 10 SiO₂ or the like.

[0025] In FIG. 3H, connecting pads 316 are respectively formed in contact with the exposed areas 310a, 312a of the first and second ohmic contact layers 310, 312. The connecting pads 316 can be made of a conductive material such as a metal or alloy of metallic materials.

15 [0026] Reference now is made to FIG. 4A~4E to describe a process of forming a base substrate according to various embodiments of the invention.

[0027] In FIG. 4A, a luminescent layer 404 is formed on a substrate 402. The substrate 402 can be made of a silicon (Si)-based material. In an embodiment, the luminescent layer 404 can be made of a zinc-selenium (ZnSe)-based material doped
 20 with iodine, aluminum, chlorine, bromine, gallium, indium or the like to provide a conductance of the n-type. A homoepitaxy growth can be conducted to form the ZnSe-based layer on the substrate 402.

[0028] In a variant embodiment, the luminescent layer 404 can be made of a material including a phosphor powder and a passivation material such as benzocyclobutene (BCB), an epoxy-based negative resist or the like. The mixture including the passivation material and the phosphor powder can be spin-coated in liquid form on the substrate 402. A heating process then is performed to solidify and form the luminescent layer 404. Notwithstanding the foregoing specific examples, it is understood that many other material associations can be suitable to form the luminescent layer.

[0029] In FIG. 4B, a passivation layer 406 is formed to cover the luminescent layer 404. The passivation layer 406 can be made of a dielectric material such as SiO₂ or the like deposited on the luminescent layer 404.

[0030] In FIG. 4C, connecting pads 408 are formed on the passivation layer 406. The connecting pads 408 are made of a conductive material such as a metal or alloy of metallic materials.

[0031] In the variant example of FIG. 4D, a reflective layer 410 can be included between the luminescent layer 404 and the substrate 402. The reflective layer 410 can be made of a metallic material or a dielectric material. In another variant example shown in FIG. 4E, the base substrate can be composed of a ZnSe-based substrate 420 on which are formed the passivation layer 406 and connecting pads 408.

[0032] FIG. 5A and 5B are schematic views of a process of mounting a light-emitting unit to a base substrate according to an embodiment of the invention. In FIG. 5A, conductive bumps 518 are formed on connecting pads 316 of the

light-emitting unit 300. In an example of implementation, the conductive bumps 518 can be made of a solder material.

[0033] In FIG. 5B, the light-emitting unit 300 is positioned so as to have the conductive bumps 518 in contact with connecting pads 408 of the base substrate 400.

5 A reflow process then is conducted to fixedly attach and connect the connecting pads 316, 408 to one another. The light-emitting unit 300 thereby is mounted and electrically connected to the base substrate 400.

[0034] FIG. 5C is a flowchart describing the process of forming a white light-emitting device according to an embodiment of the invention. The process
10 includes forming a light-emitting unit provided with a plurality of first connecting pads (502), and forming a base substrate provided with a plurality of second connecting pads (504). The light-emitting unit emits a first light radiation upon the application of a voltage bias between the first connecting pads. The base substrate is configured to emit a second light radiation when stimulated by the first light radiation. Conductive
15 bumps are formed on either the first or second connecting pads (506). The light-emitting unit and the base substrate then are assembled with the conductive bumps in contact between the first and second connecting pads (508). A reflow process then is performed to connect the first and second connecting pads to one another (510). The light-emitting unit is thereby assembled with the base substrate to form a light-emitting
20 device.

[0035] Realizations in accordance with the present invention have been described in the context of particular embodiments. These embodiments are meant to be illustrative and not limiting. Many variations, modifications, additions, and improvements are

possible. Accordingly, plural instances may be provided for components described herein as a single instance. Boundaries between various components, operations and data stores are somewhat arbitrary, and particular operations are illustrated in the context of specific illustrative configurations. Other allocations of functionality are
5 envisioned and may fall within the scope of claims that follow. Finally, structures and functionality presented as discrete components in the exemplary configurations may be implemented as a combined structure or component. These and other variations, modifications, additions, and improvements may fall within the scope of the invention as defined in the claims that follow.